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ABSTRACT

The activities in this book are designed to reinforce the elementary concepts of flight. General background information, suggested activities, questions for discussion, and answers are provided. Twenty-eight reproducible worksheets are contained in this guide. Topics include: hot air balloons, the physics of flight, air resistance, airplane movements and control, thrust, gliders, helicopters, the history of flight, kites, boomerangs, rockets, space flight, and space exploration. A crossword puzzle on space flight is included. (CW)

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Flight

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LIGHT

by Helen Frensch

The activities in this book reinforce basic elementary concepts in the study of flight, including principles of flight, history of flight, types of flying machines, and space travel.

General background information, suggested activities, questions for discussion, and answers are included.

Encourage students to keep completed pages in a folder or notebook for further reference and for review.

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Flight: Background Material

Page 1 The Montgolfier brothers, who made the first successful hot-air balloon, experimented first by filling small paper bags with smoke. They thought the smoke made the bags rise. Later they realized that hot air made the bags lighter than the surrounding air.

Page 3 Make certain that students understand why a fluid flows faster over the curved surface than over the flat surface of an airfoil (because it must flow farther in the same amount of time). Help students combine this information with Bernoulli's principle that a faster fluid causes less force than a slower fluid. This will help them to see why the pressure on the curved surface is lower than that on the flat surface and why the airfoil rises.

Page 4 Emphasize how lift and gravity are opposing forces, just as thrust and drag are also opposing forces. Point out that lift must exceed the force of gravity and that thrust must exceed drag for flight to occur.

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Page 5 Caution students to fold the paper for the leading edge with great care. If this is not done carefully, there will be ripples or twists in the leading edge that will cause problems in flying. Since the leading edge will be folded again and again for succeeding activities, it is best to do it correctly from the start.

Page 6 Airplanes move on three axes called pitch, roll, and yaw. Movable controls on the tail and wings help control these axes. Horizontal tail surfaces called elevators control pitch; the vertical tail surface, the rudder, controls yaw. The rudder of an airplane, unlike the rudder of a boat is not the primary turning control during flight. The Wright brothers proved that an airplane turns by banking its wings. However, on the ground the rudder is the primary steering control. The surfaces called ailerons on the outside trailing edges of the wings control roll.

Page 7 In these activities, students will find that the greater care they exercise in folding their paper gliders, the smoother its flight. Care must be taken that both sides of a glider are perfectly symmetrical. The same is true of adjustable horizontal surfaces that curve upwards to form the elevators.

Pages 8–9 The combined use of roll control (change in angle of attack of one wing with respect to the other) and rudder control was an important part of the Wright brothers' control system. The Wright brothers also learned that for an airplane to make a properly coordinated turn, roll and yaw controls needed to be supplied together in the right proportion.

Page 10 Students will find that their latest model is better balanced than their previous attempts. Encourage them to improve their glider's performance in other ways. Have them study the center line to make sure the glider is symmetrical. If one wing has more angle of attack than the other, the glider will roll to one side. Have them also take care that the rudders and fins are set at the same angle to the center line.

Page 11 Airplanes acquire thrust either from the twirling of propellers or by the reaction in jet engines, as hot gases are forced from the rear of the engines at tremendous speed, causing the engine to move forward at an equally high speed.

Page 12 Gliders must search for updrafts in order to gain altitude and to soar. Updrafts can be found as slope winds that blow against a hill are deflected upward. The heat given off by cities can also produce thermals. They may be present from late morning to late afternoon on a sunny day.

Page 13 A single-rotor helicopter has one main rotor mounted above its body. It has a smaller rotor mounted on its tail. A tandem-rotor helicopter has a main rotor above each end of its body. A special-rotor helicopter has one rotor above the other. Point out that the term *coaxial* is derived from the fact that the upper rotor turns inside the shaft of the lower rotor.

Pages 14–15 The early planes flew slowly, within the range of 21 to 35 miles per hour. The first successful flight by the Wright brothers in 1903 was not an immediate media success as it would have been today. In fact, it took five years before the world began to believe that the Wright brothers could fly. When the Wrights offered their ideas to the U.S. Army for $100,000, their offer was rejected. The army later offered them a contract worth $25,000.

Pages 16–17 Remind students to practice what they have learned about lift, drag, and balance while flying their kite.

Page 18 The boomerang spins wing over wing in flight when thrown correctly. Because of its shape, there is lower pressure above each wing than below. This keeps the boomerang in the air. The boomerang flies forward, rises, and curves to one side.

Page 20 K. E. Ziolkowski, a Russian; Robert Goddard, an American; and H. Oberth, a naturalized German of Romanian birth showed that the most efficient way to develop reaction force is to accelerate a stream of very fine particles to very high speeds. One way to generate the fine particles is to cause two chemicals to react to form gaseous products. Between 1919 and 1929, Dr. Goddard made the first successful liquid-

propellant rocket flight, developed gyroscopes for rocket flight control, and was the first to apply instruments to record conditions on the rocket flight.

Page 21 The *Saturn V* rocket stood 363 feet high and required a thrust of 7,570,000 pounds. It carried a payload of 285,000 pounds when in earth orbit and 101,000 pounds to the moon.

Page 22 A string may be substituted for dental floss. A space vehicle can stay above the surface of earth because its velocity creates a centrifugal effect which is opposite to the downward pull of gravity.

Page 23 The horizontal speed that a satellite must have in order to stay in orbit around earth varies with the distance from earth. For example, a satellite 200 miles from earth's surface must have a speed of 18,000 miles per hour to remain in orbit. The moon—a satellite in orbit 238,857 miles from earth—has an average speed of 2300 miles per hour.

Page 24 A space shuttle can lift 65,000 pounds into orbit with a crew of seven. It can also recover satellites and bring them back to earth for repair.

Page 25 When the space shuttle prepares to return to earth, it is still 200 miles above the earth and is traveling at a speed of over 17,000 miles per hour. To prepare for deorbit burn, the orbiter turns around so it is traveling tail-first. The orbital maneuvering rockets are burned to reduce the speed by 200 mph. Then the orbiter is turned once more so it is raised to an angle between 28 and 38 degrees in order to lessen speed. After 30 minutes the space shuttle descends 400,000 feet. Tremendous heat builds up and a communication blackout occurs, which lasts for 12 minutes.

Page 26 To overcome the sun's gravitational pull, a rocket would have to reach a speed of 26 miles per second or 93,000 miles per hour with respect to the sun. Earth is already moving at 18.5 miles per second around the sun. So a rocket leaving earth in the same direction as the earth would have to attain an additional speed of 7.5 miles per second to leave the sun's orbit.

Page 27 Have students do research on the fantastic trip of *Voyager II* as it flew past Neptune and out of the solar system. Scientists have calculated where *Voyager* might be in the galaxy at various times in the future.

Flight: Answers

Page 1
1. Hot air is lighter than cold air; so balloons filled with hot air weigh less than the air around them. 2. The balloon is pushed up by the cooler air around it; wind. 3. escapes through the cooling vent

Page 2
1. It lifts up. 2. The air pressure on the top surface of the paper strip is lower than the air pressure beneath it.

Page 3
1. The air on top of the wing must travel faster because it must travel farther in the same amount of time as the air on the bottom of the wing. 2. on the bottom of the wing 3. Since the air over the top of the airfoil is faster, it causes less pressure on the top of the wing than beneath it, making it rise.

Page 4
1. gravity, lift, drag, and thrust 2. lift; thrust 3. thrust

Page 5
1. The leading edge of an airplane cuts through the air and overcomes air resistance. 2. The cone always falls straight down on its point.

Page 6
1. when its nose is pointed downward 2. when its nose is pointed upward

Page 7
The elevators help control the pitch of the glider.

Page 8
By making the wings higher, I was able to keep the glider from rolling.

Page 9
1. Answers will vary. Students may find that a slight twist of the rudder to the right straightens it out. 2. by bending the rudder to the left 3. by bending the rudder to the right.

Page 10
1. The glider became balanced when its center of gravity and center of lift were at or near the same point. 2. They helped the glider fly straight.

Page 11
1. toward the nearest wall 2. in the opposite direction 3. The action of the released air caused a reaction on the balloon, causing it to move in the opposite direction just as a jet plane moves in reaction to the escaping gases.

Page 12
1. A thermal is a rising column of warm air that lifts the glider higher. 2. A variometer shows the rate at which the glider rises or sinks, which helps a pilot find rising air currents. 3. The rising air currents help give the hang glider lift.

Page 13
1. Answers will vary depending on art selections. 2. for rescuing stranded people, firefighting, construction of skyscrapers, policing traffic, aerial photography, TV coverage, as air taxis. A force seems to be lifting the kite.

Page 14
1. Wilbur and Orville Wright 2. France 3. glider 4. steam-powered model airplane

Page 15
1. 84 days 2. Charles Yeager 3. Their flight was nonstop around the world without refueling. 4. Amelia Earhart

Page 17
1. An upward angle against the wind provides enough lift to overcome the forces of drag and gravity. 2. Flat kites are not shaped like an airfoil, so Bernoulli's principle has no effect on them. 4. string 5. gravity

Page 18
1. In an airplane both leading edges are on the outside of the wing, one on the right, the other on the left. 2. In a boomerang both leading edges are on the right side, one on the outside and the another on the inside.

Page 19
1. hot air is lighter than cold air, and the balloon is pushed up by the cooler air. 2. air pressure 3. gravity 4. Bernoulli's principle 5. less 6. faster 7. gravity, lift, thrust, and drag (or air resistance) 8. lift 9. thrust 10. air resistance, or drag 11. Pitch 12. Roll 13. Yaw 14. left aileron; right aileron 15. elevators 16. rudders 17. center of gravity 18. thrust 19. a reaction on the plane which moves the plane forward, in the opposite direction from the escaping gases. 20. helicopter

Page 20
1. gravity and air resistance 2. The rocket gets lighter each time it uses up fuel and drops off the stage that carried the fuel; in this way the rocket is able to travel farther.

Page 21
1. 100 miles from Earth 2. enough fuel to lift all the stages. 3. *Saturn V*

Page 22
perigee 1. The water stays in orbit because the cup is swinging fast enough. 2. The water spills because the cup is not swinging fast enough to keep it in orbit. 3. Although the object in orbit is falling toward earth, it is traveling at a speed that never lets it touch earth because earth curves downward at the same rate as the object in orbit falls. 4. An object farther from earth has a larger orbit, which makes it take longer to travel on it. Also, an object farther from earth travels more slowly.

Page 23
1. by rockets 2. communication, weather studies, navigation of ships, scientific investigation 3. It leaves orbit and falls back toward earth.

Page 24
The space shuttle gets thrust from two solid rocket boosters and from its own rocket engines supplied with fuel from the huge external tank. Its rocket engines are too powerful to be used for a landing, and besides the orbiter has no fuel at that time.

Page 25
1. T 2. F 3. T 4. F 5. T

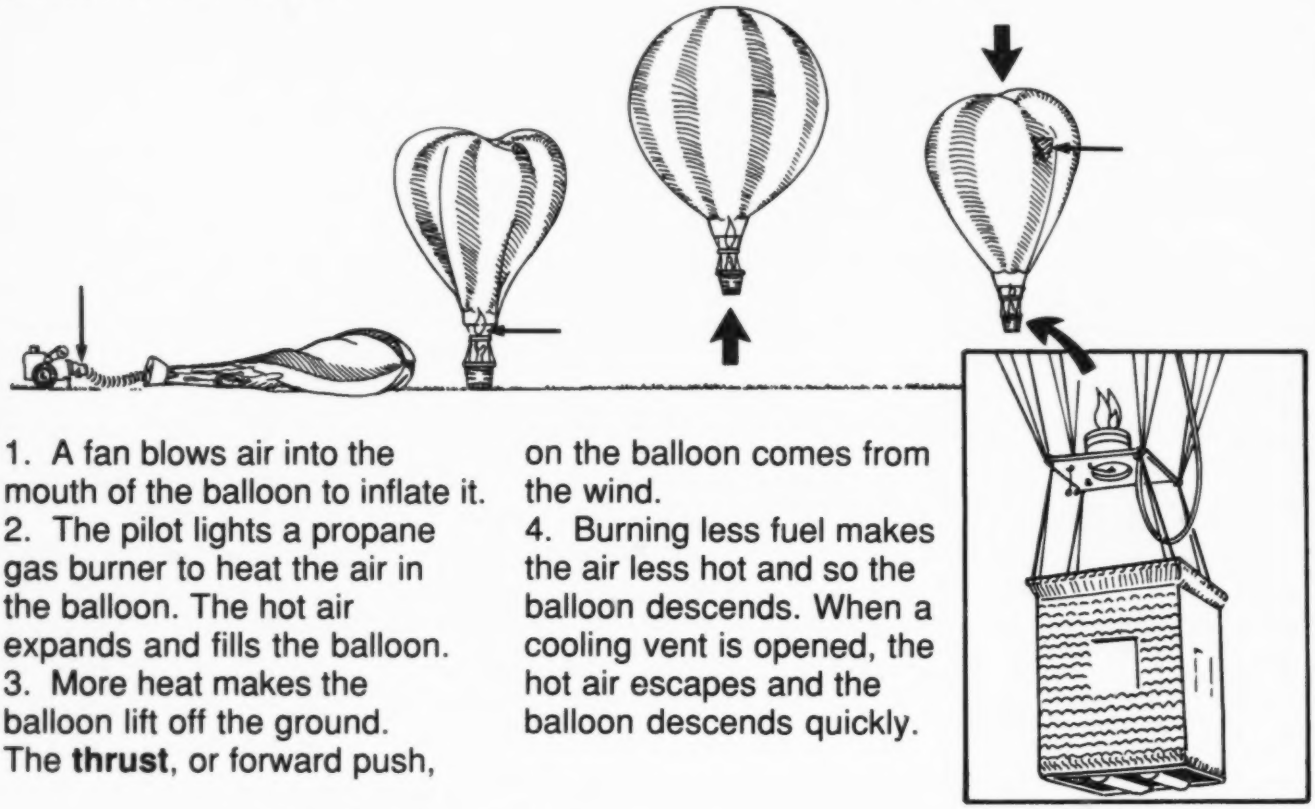
Page 26
1. 38,880 km or 24,300 mi. per hour 2. 40,000 km or 25,000 mi. per hour 3. 42,620 km or 26,640 mi. per hour 4. the sun

Page 27
1. robots 2. *Viking IV*; 3. 4; 7 billion; 12 4. Neptune; solar system; deep space

Page 28

HOT-AIR BALLOONS

Hot air is lighter than cold air. Balloons filled with hot air rise because they weigh less than the air around them. The balloon is pushed up by the cooler air around it.



1. A fan blows air into the mouth of the balloon to inflate it.
2. The pilot lights a propane gas burner to heat the air in the balloon. The hot air expands and fills the balloon.
3. More heat makes the balloon lift off the ground. The **thrust**, or forward push, on the balloon comes from the wind.
4. Burning less fuel makes the air less hot and so the balloon descends. When a cooling vent is opened, the hot air escapes and the balloon descends quickly.

1. A hot-air balloon lifts off because _____.

2. The thrust on a hot-air balloon comes from the _____.

3. A balloon descends when the hot air _____.

ACTIVITY Launch a helium-filled balloon with a stamped postcard addressed to your school. Each card should look like this:

Where did you find the balloon? _____

Date of recovery: _____

Thank you for taking the trouble to mail this postcard to my school!

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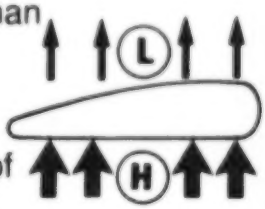
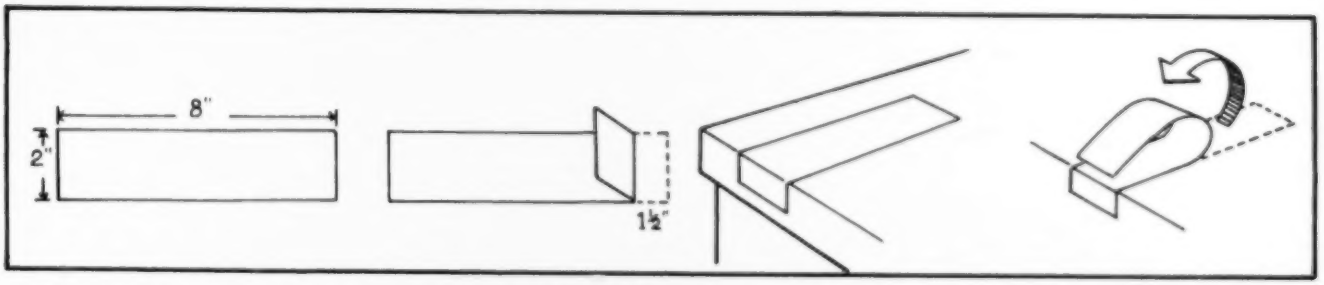
WHAT MAKES AN AIRPLANE FLY?

When you jump up off the ground, a force always pulls you back. Even if you throw a ball up, it falls down. The force of gravity pulls both you and the ball back to earth. How can an airplane which may weigh more than 34,000 kilograms (75,000 lbs.) stay in the air?



Lift is the upward force that opposes the force of gravity. A moving airplane has lift because of its motion through the air and the shape of its wings. Air flows over the surface of the wings. Notice that airplane wings are curved more on top than they are on the bottom. A shape like that of airplane wings is called an **airfoil**.

Lift occurs because the air pressure on the top surface of an airfoil is less than the air pressure beneath the airfoil. The greater air pressure beneath pushes the airfoil upward.



ACTIVITY Make an airfoil by cutting a strip of paper 5 x 20 cm (2 x 8 in.). Fold back 3.7 cm (1 1/2 in.) of the long strip. Crease the fold with your thumbnail. Turn the paper over and then crease the fold the other way. Hold the crease tightly at the edge of a desk or table with the 3.7 cm part hanging down. Lift the other end of the paper and curve it outward over the crease. Now hold the flat part of the paper on your lower lip, with the curve facing upward. Blow across the top of the curved surface.

1. What happens to the curved part of the paper? _____

2. What causes this change in the curved part of the paper strip? _____

_____

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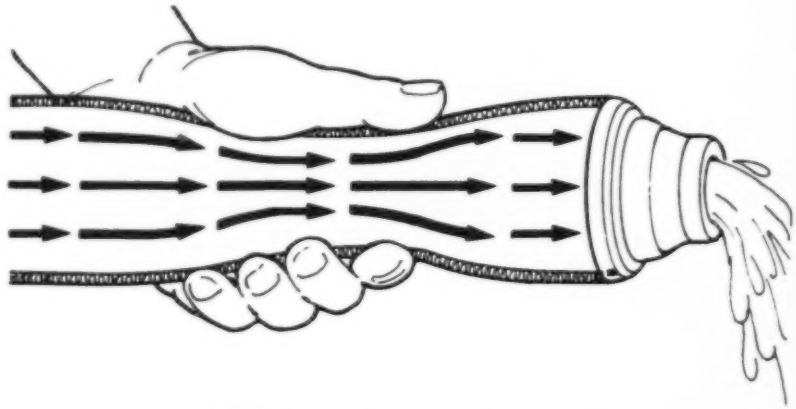
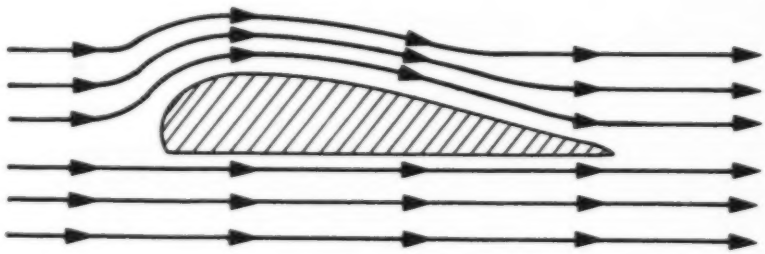
BERNOULLI'S PRINCIPLE

What causes the air pressure on the upper surface of an airfoil to be lower than the air pressure below? Daniel Bernoulli (1700-1782), a Swiss mathematician, studied air and fluids such as water. He found that if a fluid is moving along a surface, it causes a force to be exerted at a right angle to the surface. He also found that a faster-flowing fluid causes less force than a slower-flowing fluid. This effect is known as **Bernoulli's principle**.

First look at what happens to water flowing through a rubber hose. A certain amount of water goes through the hose in one minute. If you squeeze the hose, water will flow faster in that section. Why does this happen? The same amount of water that traveled through the wider hose in one minute must now travel through the squeezed hose in one minute. The water must travel faster in the narrow part of the hose so that all the water passes through the hose in the same amount of time.





Now look at the picture of the airplane wing. The wing is curved on top, so the air flowing over the upper surface of the wing must travel farther than the air along the bottom of the wing in the same amount of time.

ACTIVITY

1. Which air must travel faster, the air on top of the wing or the air beneath the wing?_____
2. On which part of the wing is there more air pressure?_____
3. How does Bernoulli's principle explain why an airfoil rises?_____

_____

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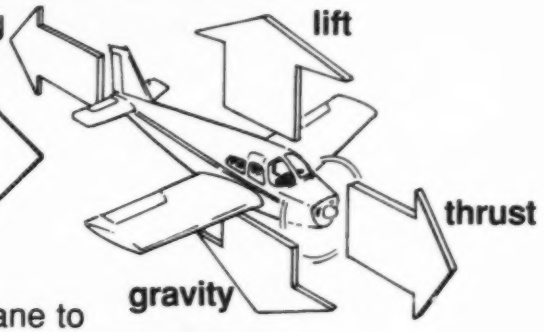
FORCES ON AN AIRPLANE

Four forces act on a moving airplane: **gravity**, **lift**, **thrust**, and **drag**.



Gravity keeps a plane on the ground or pulls a plane to earth when it is in the air. The pull of gravity equals the weight of the plane.

You have already seen that a plane will never leave the ground unless a force called **lift** is created under its wings. When a plane moves rapidly on the ground or in the air, air pressure above the wings is less than air pressure below the wings. This causes a lift on the wings. Lift must be greater than the pull of gravity in order for the plane to stay in the air.

A plane produces lift when it moves forward through the air. The force that moves a plane forward is called **thrust**. The engine helps produce thrust on the plane.

Drag is the force that opposes thrust. It is also known as air resistance. As thrust increases, so does drag. For a plane to move forward, it must have more thrust than drag.

ACTIVITY Hold an eraser on your left, outstretched hand. Can you feel the pull of gravity on the eraser? To be sure you do, lift the eraser with your right hand just enough so it barely touches your left hand. You are providing lift that just balances the pull of gravity.

ACTIVITY Hold the eraser between your left thumb and index finger. Move the eraser through the air to the left. You are providing thrust to the left. With your right index finger and thumb take hold of the right end of the eraser and pull to the right. You are providing drag to the right. Only if thrust is greater than drag does the plane move forward.

1. What are the four forces that act on a moving plane?_____

_____

2. Which force opposes gravity?_____ Opposes drag?_____

3. Which force moves a plane forward?_____

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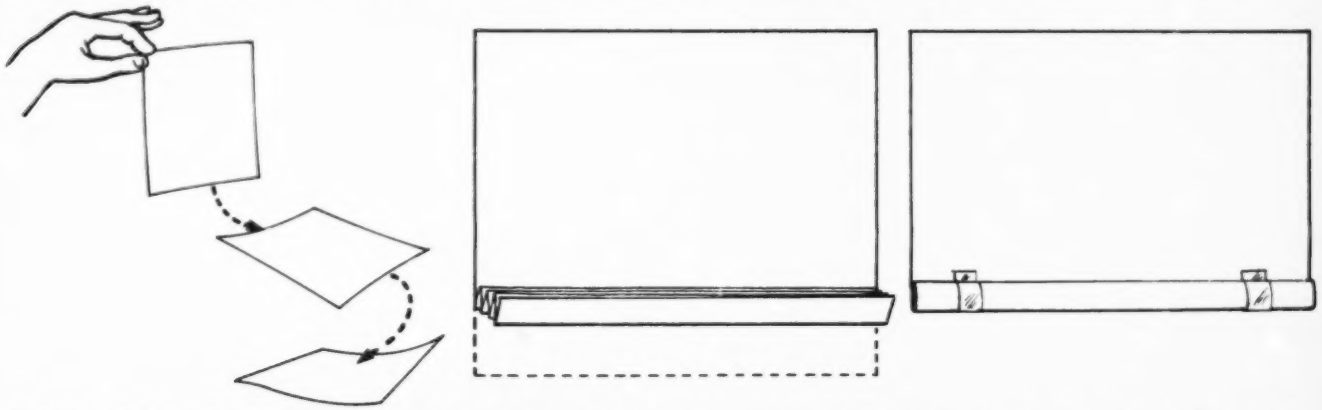
OVERCOMING AIR RESISTANCE

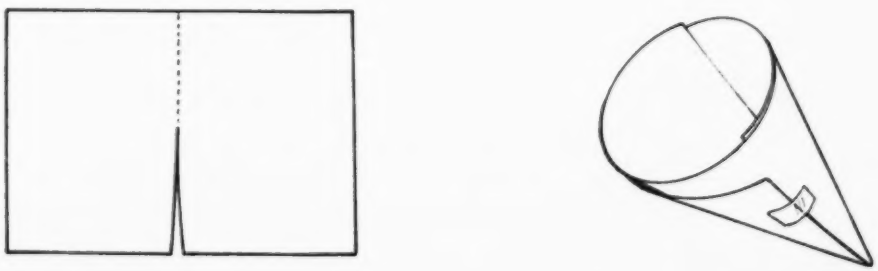
Just as water resists the body of a swimmer, air resists an object that tries to fly through it. Find out how air resistance can be overcome.



ACTIVITY Hold a sheet of paper as high as you can above your head. Let go and watch how the paper falls. The paper is unstable and falls to the side because of air resistance. Carefully fold over the long edge of the paper five times. Tape this folded part to the rest of the sheet to make what is called a **leading edge**. Let go and watch how the paper falls. Which part always reaches the floor first? The leading edge is a part that cuts through the air and helps overcome air resistance. The paper with a leading edge is more stable than a plain sheet of paper.

How does the leading edge of an airplane wing overcome air resistance?

_____



ACTIVITY Fold another sheet of paper along the middle of the long side and cut to the center of the paper. Form a cone with the paper and tape it closed. Hold the cone high and let it fall. Is the cone more stable than the paper with a leading edge? Why do you think so? Experiment with other cones. Make a very wide cone and a very narrow cone. Which is more stable? Drop the cone on its side, upside down, and at an angle. The streamline shape of the cone's point causes less air resistance.

How does it always fall?_____

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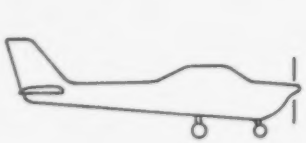
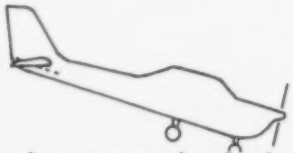
BASIC MOVEMENTS OF AN AIRPLANE

An airplane has three basic movements: **pitch**, **roll**, and **yaw**.
Pitch is the upward or downward motion of the nose of a plane.



level flight



downward pitch

upward pitch

1. When does the plane have downward pitch?_____

2. When does it have upward pitch?_____

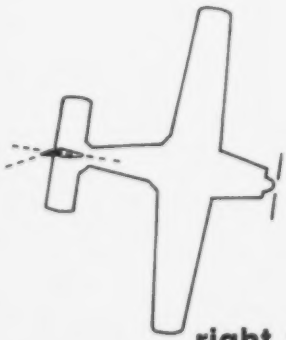
Roll is the motion that occurs when one wing dips lower than the other. When the plane rolls toward the right, it is called a right bank. A roll to the left is called a left bank.

left bank

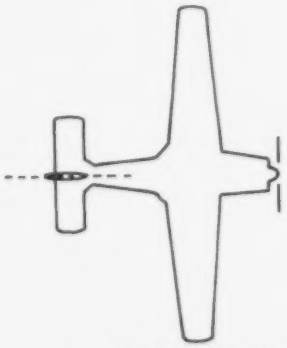
level flight

right bank

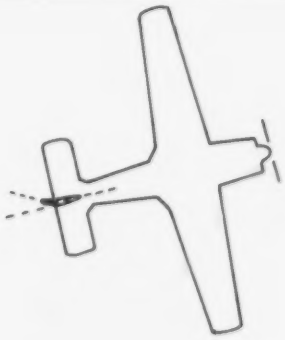
Yaw is the motion of a plane as the nose turns left or right.



right yaw



level flight



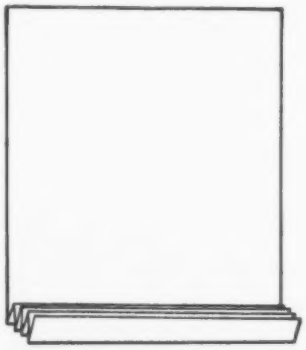
left yaw

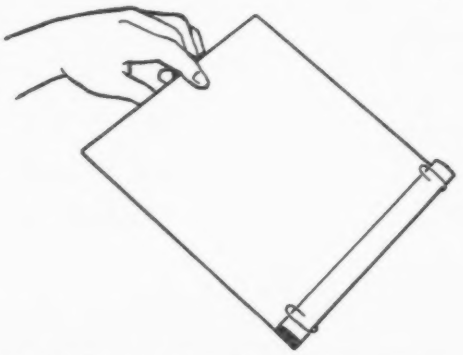
ACTIVITY Practice the three basic movements of an airplane. With an eraser, show upward pitch, right bank, right yaw, left bank, downward pitch, and left yaw..

13

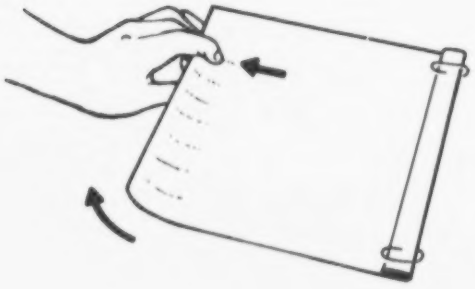
CONTROLLING PITCH

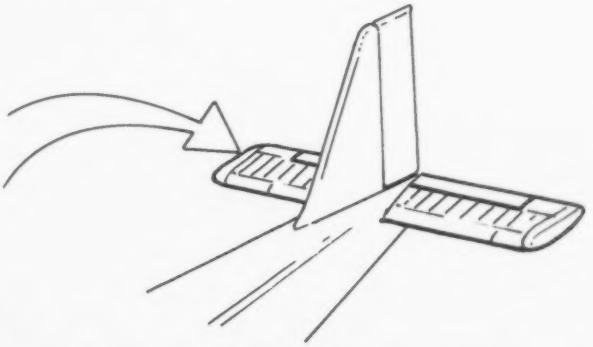
You have discovered how to overcome air resistance by changing the shape of your paper glider. See what happens when you launch your paper glider in a horizontal position.





ACTIVITY Use the sheet of paper on which you folded a leading edge. If necessary prepare a new sheet by folding the long edge five or six times. Tape the edge down. Place a paper clip at either end of the leading edge. Hold the trailing edge between your thumb and index finger to launch your glider. If you are lucky, it will glide smoothly.





ACTIVITY With your thumb under the paper, pull your index fingernail on the paper toward the trailing edge, giving it an upward turn. You are making an **elevator** on the "wing." The elevator helps control the pitch of the glider. To launch the glider, hold it up high and let go with a slight forward motion. If you launch your glider with too much force, it will be out of control and the glider will not be able to take advantage of the lifting force of the air. Like the Wright brothers, you are experimenting by adding controls to your plane.

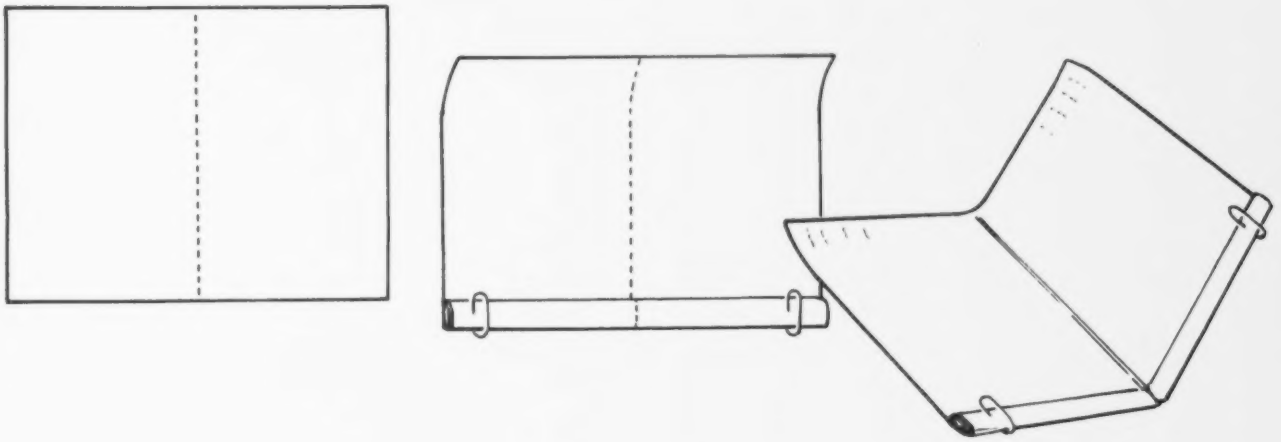
You have added elevators to your glider. What do the elevators do?

_____

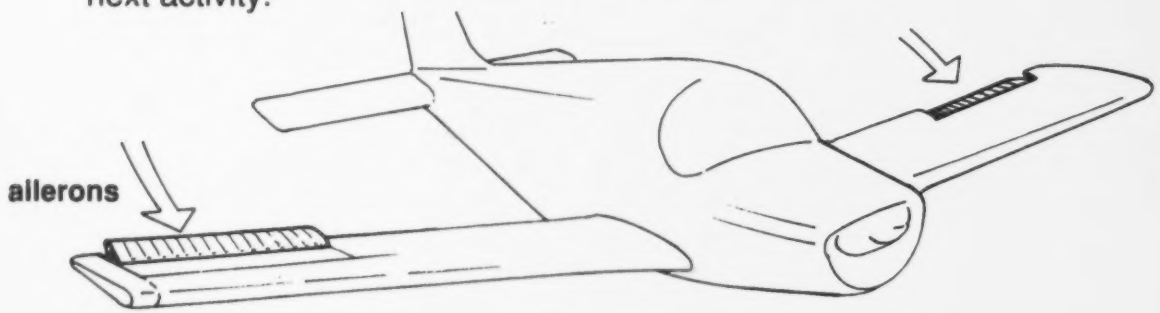
_____

CONTROLLING ROLL

Perhaps your glider rolls to one side. Roll can be controlled by making the glider wings higher than the center line.



ACTIVITY Hold a sheet of paper along the long edge and bring the two ends together to make a crease along the center line. With the center indent facing up, make a leading edge with paper clips as shown. Also give the glider elevators as before. Bend the glider upward as shown. You now have a glider with wings. Adjust the wings so that they are exactly the same on both sides. Launch your glider several times. Save it for the next activity.



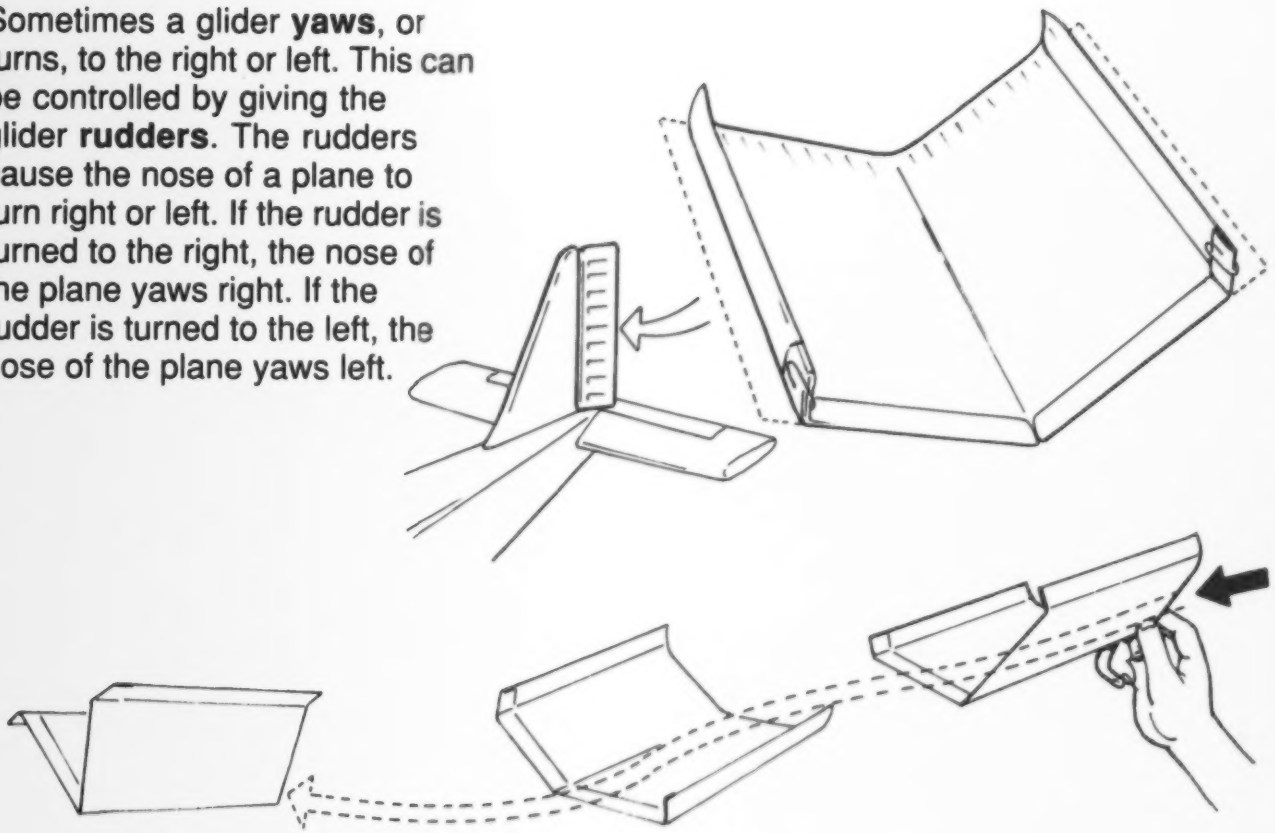
The angle you gave the glider to control roll is like the **ailerons** (**ay'** ler onz) of a plane. A plane rolls or banks to the left when the left aileron is up and the right aileron down. It rolls or banks to the right when the right aileron is up and the left aileron is down.

How did you make the glider more stable?_____

_____

CONTROLLING YAW

Sometimes a glider **yaws**, or turns, to the right or left. This can be controlled by giving the glider **rudders**. The rudders cause the nose of a plane to turn right or left. If the rudder is turned to the right, the nose of the plane yaws right. If the rudder is turned to the left, the nose of the plane yaws left.



ACTIVITY Give your glider rudders. Fold the ends of the glider's wings upward 1.3 cm (1/2 in.) on either side as shown. Launch the glider. Does your glider fly straight forward? If not, check that the glider is exactly the same on both sides. Bend the front tip of the right rudder to the right. Launch the glider. The glider should turn right. Try this a few times. Straighten the right rudder. Bend the front tip of the left rudder to the left. The glider should turn left. You may have to experiment to get your glider lined up properly.

1. How would you control a glider that yaws to the left?_____

_____

2. How does a pilot turn the nose of a plane to the left?_____

_____

to the right?_____

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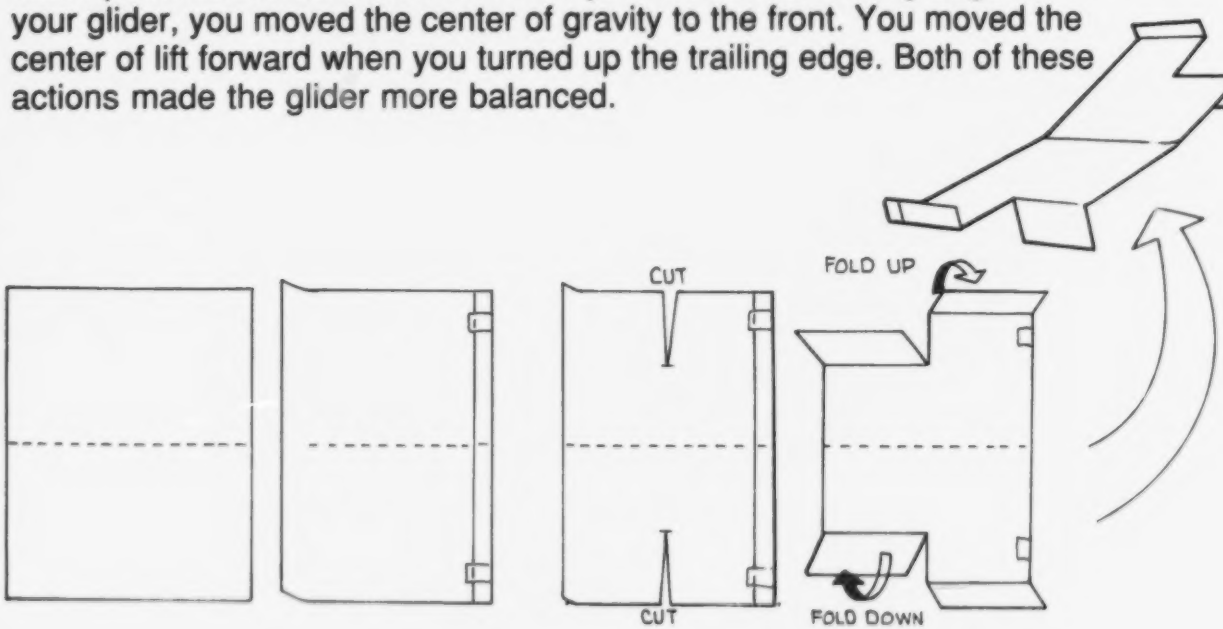
ACHIEVING BALANCE

A pilot of a plane brings the four forces of flight–gravity, lift, thrust, and drag–into balance when flying the plane. The center of gravity and the center of lift are important to balance. The **center of gravity** is the point at which the mass of the plane seems to be concentrated. The **center of lift** is the point at which a plane's total lift seems to be concentrated. A plane is balanced when the center of gravity is at the same point as the center of lift. When you folded the leading edge of your glider, you moved the center of gravity to the front. You moved the center of lift forward when you turned up the trailing edge. Both of these actions made the glider more balanced.



ACTIVITY Make a more balanced glider by folding a sheet of typing paper in half widthwise. Open the sheet with the crease facing up. Then fold the sheet lengthwise. Open it again with the longer crease facing down. Make a leading edge by folding over 0.6 cm (1/4 in.) of paper on the long edge. Keep folding the paper carefully up to the crease. Then tape the folded part down. Place the taped side facing down. Curl up the trailing edge slightly. Make a mark halfway between the leading edge and the trailing edge on each side. Cut in 3.7 cm (1 1/2 in.) from the side of the glider at the marks. Turn down a 3.7 cm (1 1/2 in.) flap on each side at the rear of the glider to make rudders as shown. Fold up a 1.3 cm (1/2 in.) strip on either side of the front of the glider to make wing fins. Fly your new glider.

1. What gave the glider balance?_____

2. How did the rudders and wing fins help?_____

_____

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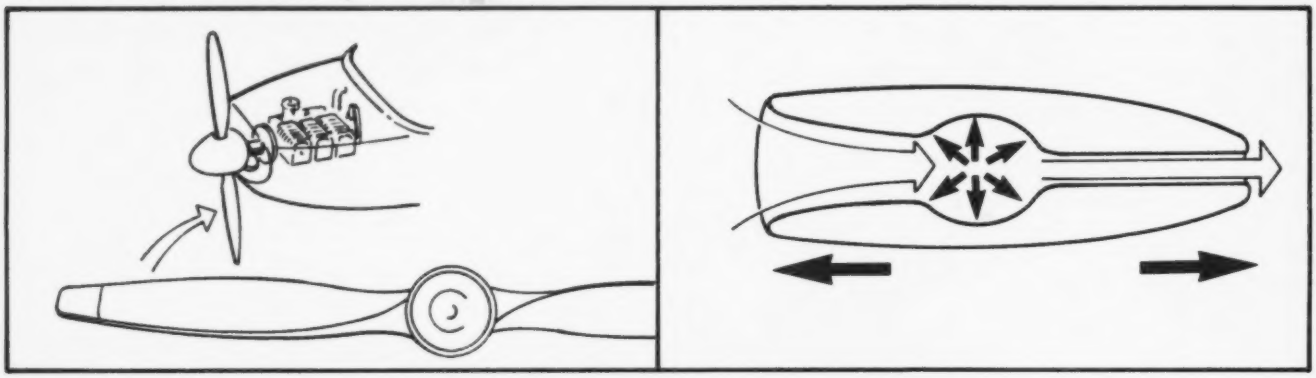
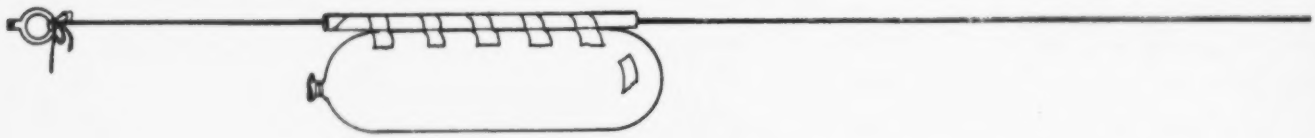
THRUST FROM PROPELLERS AND JETS

A plane does not have lift unless it is moving forward. Do you remember why? Some airplanes are powered by a gasoline engine. The engine helps move the **propellers**, which provide thrust, or the forward motion of the plane. The propeller blades have the shape of an airfoil. They have a leading edge and a trailing edge. The blades are moved by a shaft which is driven by the engine.



Jet planes do not have propellers. How do they achieve forward motion? Jets take in air through the front of the engine and then compress, or squeeze the air in a small space. The compressed air is sprayed with fuel and burned. The hot air and fuel expand, or spread out, and are forced out the rear of the engine. The **action** of the hot gases being forced from the rear of the plane causes a **reaction** on the plane which moves it in the opposite direction.



ACTIVITY Show how a jet plane moves forward as a result of action and reaction. Pull one end of a long string through a large soda straw. Ask a partner to fill a long balloon with air and hold it tightly closed. Tape the balloon to the straw all along the length of the straw. Face the mouth of the balloon toward the nearest wall and tie one end of the string to a stable object on that wall. Tie the other end of the string to an object on the opposite side of the room. Release the balloon.

1. In what direction did the air from the balloon go?_____

2. In what direction did the balloon go?_____

3. How is your balloon like a jet plane?_____

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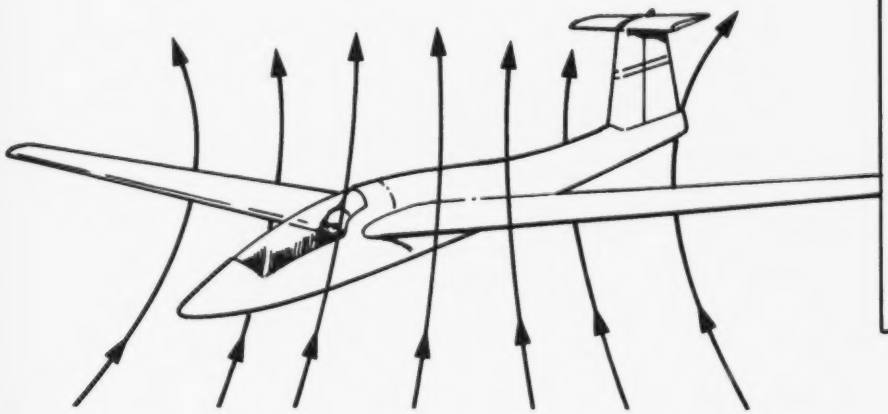
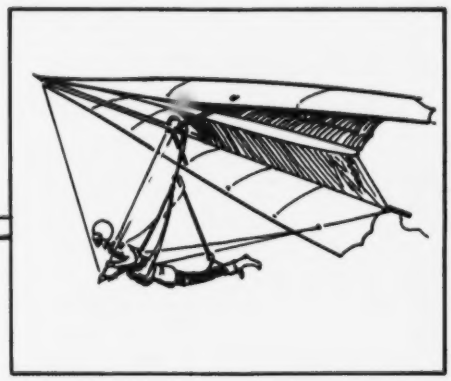
GLIDERS

A **glider** is an airplane without an engine. Gliders, like other airplanes, do not have lift unless they move forward rapidly. Without an engine, a glider must be launched. Sometimes a long steel cable wound on a powered drum pulls a glider into the air. At other times, an airplane or a truck tows the glider until it gets a lift on its wings. Once in the air, the glider pilot searches for a **thermal**. A thermal is a rising column of warm air. The thermal helps lift the glider higher.

Gliders have the same controls as an airplane. Some gliders have tail parachutes to slow them down for a landing. They may also have an instrument called a **variometer** which shows the rate at which the glider rises or sinks. This helps the pilot find rising air currents.





ACTIVITY Hold one of your paper gliders over a radiator or other warm surface. Notice the added lift the glider gets from the rising air.

A **hang glider** is a sail attached to an aluminum frame. The pilot flying the hang glider takes off by running down the windward side of a cliff. The sail billows out, creating an airfoil. When the glider has enough lift, it takes off. The pilot steers the glider with a control bar.

1. Why does a glider pilot search for thermals?_____

2. How does a variometer help a glider pilot find rising air currents?_____

_____

3. Why does a hang glider run down the windward side of a cliff?_____

_____

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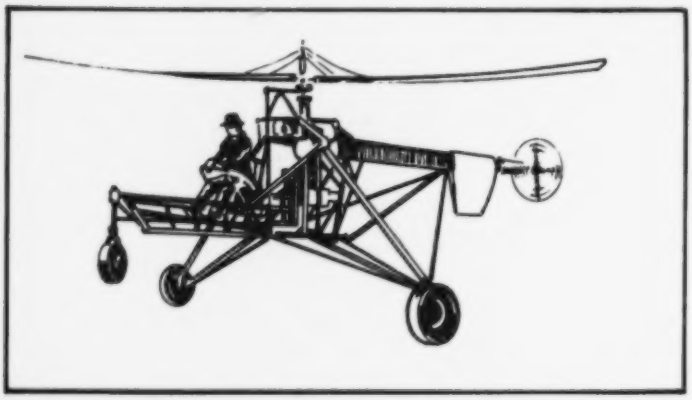
HELICOPTERS



Helicopters can take off or land vertically. They can fly forward, backward, or sideways. The first practical helicopter, the VS-316A, was built by a Russian-born American engineer, Igor Sikorsky, in 1942.

A helicopter has long blades that rotate above it. The rotating blades are part of the **rotor**. Shaped like airfoils, the rotating blades are like wings that give the helicopter lift.

A blade spinning in one direction would cause the helicopter to rotate out of control in the opposite direction. (Have you ever noticed how a ceiling fan "wobbles" as its blades spin?) A second blade, smaller than the first, and rotating in the opposite direction prevents a helicopter from spinning. The second rotating blade may be mounted on the rear end of the helicopter.

The blades of the helicopter are inclined, with the leading edge upwards. This increases the lift. Even more pitch is needed for the helicopter to climb higher. The pilot moves the pitch lever up in order to climb. To move forward, the rotor has to be tilted forward.

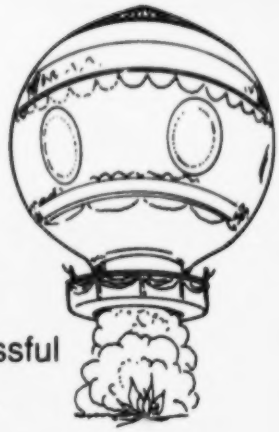
1. How are the rotors of these helicopters different?_____

2. What are some uses of helicopters?_____

ACTIVITY First find out what direction the wind is coming from. Then hold a kite flat, pointing into the wind. Notice if the kite lifts up. Raise the front of the kite slightly.

What happens to the kite?_____

HISTORY OF FLIGHT



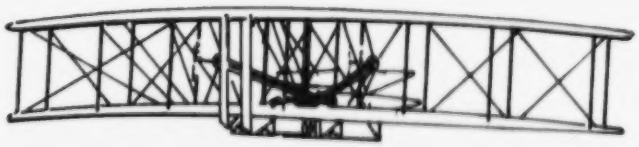
People have thought about flying for hundreds of years. The first successful attempts are listed below.

1783 Two Frenchmen, Jean F. Pilatre de Rozier and the Marquis d'Arlandes, floated for five miles over Paris in the first successful hot-air balloon flight.

1804 Sir George Cayley of England built the first glider that flew without a passenger.

1891 Otto Lilienthal of Germany made the first glider that flew with a passenger.

1896 Samuel Langley, an American scientist, built a steam-powered model airplane that flew.



1903 Wilbur and Orville Wright built the first successful airplane. It had a gasoline engine and two propellers. Orville flew this heavier-than-air plane. The plane was balanced and could be controlled by turning one wing tip or the other during flight.

1. The first successful heavier-than-air plane was built by _____.

2. The first successful hot-air balloon was flown in _____.

3. Otto Lilienthal made the first _____ that flew with a passenger.

4. Samuel Langley's contribution to flight was a _____.

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FLIGHTS TO REMEMBER

First Airplane Flight
Orville and Wilbur Wright
1903, Kitty Hawk, North Carolina

First Transcontinental Flight
Calbraith Rodgers
1911, New York to California
(took 84 days)

First Nonstop Transatlantic Flight
John Alcock and Arthur Brown
1919, Newfoundland to Ireland

First Solo Nonstop Transatlantic Flight
Charles A. Lindbergh
1927, Garden City, New York to Paris
(took 33 1/2 hours)

First Nonstop Transpacific Flight
Clyde Pangborn and Hugh Herndon
1931, Tokyo to Wenatchee, Washington

First Solo Atlantic Flight by a Woman
Amelia Earhart
1932, Newfoundland to Ireland
(took 15 hours, 18 minutes)

First Supersonic Flight
Charles E. Yeager
1947 (broke the sound barrier)

First Nonstop Flight Around the World With In-Air Refueling
U.S Air Force Crew
1949 (3 days, 22 hours)

First Nonstop Flight Around the World Without Refueling
Jeana Yeager and Dick Rutan
1986 (9 days)

ACTIVITY Play a guessing game with a partner to help you remember the important airplane flights.

1. How long did the first flight across the United States take?_____

2. Who first broke the sound barrier?_____

3. What was unique about the famous flight of Jeana Yeager and Dick Rutan in 1986?_____

4. Who was the first woman to fly solo across the Atlantic Ocean?

_____

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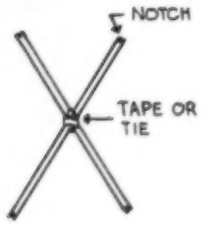
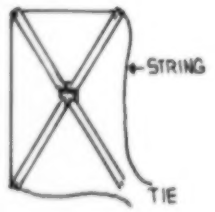
MAKING A KITE

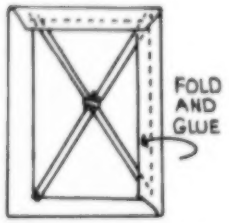


MATERIALS

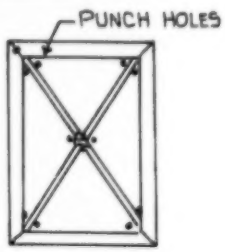
sheet of paper 21.3 x 27.5 cm (8 1/2 x 11 in.)–colored if possible
2 thin sticks (like those used for supporting plants)
thin, strong string
spool of strong thread
1 piece of heavy cardboard
strong tape
glue
5 cm wide cloth, 1 meter long (2 in. x 3 ft.)

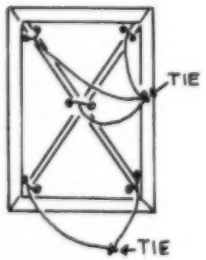


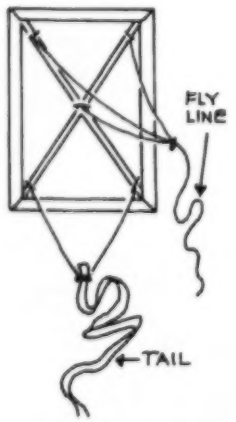
ACTIVITY



1. Have an adult cut your sticks so that each is exactly 30 cm (12 in.) long. You may also want to have the sticks split to make sure they are light enough. Ask to have a small notch cut at the end of each stick.
2. Cross the sticks to form an X. Tie or tape the sticks firmly together. Lay a string along the outer boundary made by the sticks. Press the string into the notches at the ends of the sticks. Then tie the string so it forms a rectangular frame.
3. Lay the frame on the colored paper. Fold each side of the paper over the frame and glue it to the back of the paper.
4. Make a hole with the point of a pencil on either side of each stick, about 1.3 cm (1/2 in.) from the end. Also make a hole on either side where the two sticks cross.
5. Cut 5 pieces of string 20 cm (8 in.) long. Thread the end of a string through one pair of holes. The string will cross over the stick to the other hole. Pull that end of the string to the other side also. On the front side of the kite, tie the string close to one end, leaving the rest of the string hanging as a bridle. Do the same with the other strings at the other pairs of holes.
6. Bring together the two upper strings with the center string. Tie these three ends together in a knot. Attach the long thread 30 m. (100 ft.) to where the knot is, to make the fly line.
7. Tie the two strings at the bottom of the kite together. Attach the cloth as a tail to where these two strings join. If the kite is too heavy, cut some of the tail. If it is unstable, add some tail.
8. Try flying your kite and write a brief report on how different factors–wind speed, direction, length of string, length of tail–affected its flight.







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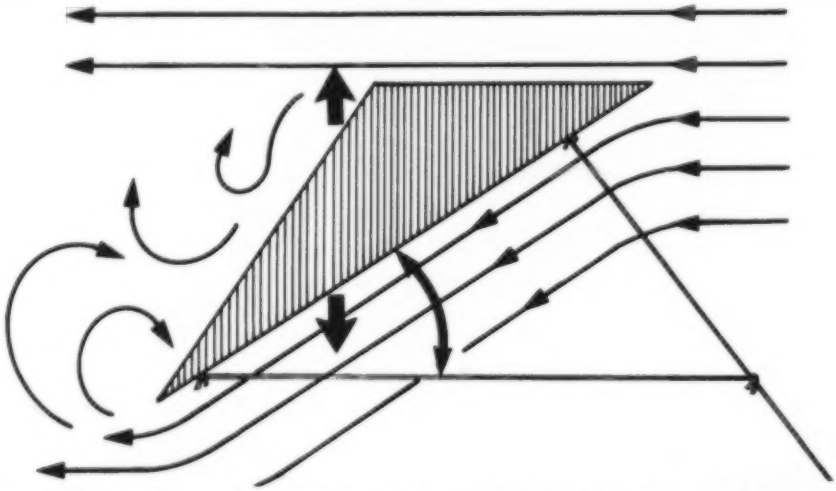
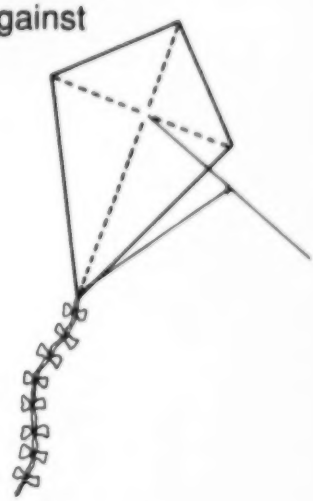
FLYING A KITE

Some of the same forces that act on an airplane keep a kite in the air. Flat kites are not shaped like an airfoil, however, so Bernoulli's principle has no effect on their flight. A kite is usually flown at an upward angle against the wind. This is called the **angle of attack**. This angle provides enough lift to overcome drag and gravity. The kite should face the wind so the force of the wind can provide lift. Thermal updraft (rising warm air) may also provide lift to a kite. The kite stays in the air when lift overcomes gravity and when the force of the wind is balanced against the force of your pull on the string.





ACTIVITY Hold your kite by the bridle facing the wind. Place the kite in an upright position. From a 15 m. (50 ft.) distance, snag the line upward. Give it line, a little at a time. When it catches a current of air, it will fly. Use the cardboard to wrap your string.

1. How does the angle of attack work in lifting a kite? _____

   _____

2. Why is Bernoulli's principle not effective in lifting a flat kite? _____

   _____

3. Label the forces (lift, gravity, wind, string) that act on the kite.

4. Which force on the kite is like the thrust of an airplane? _____

5. Which force is like drag? _____

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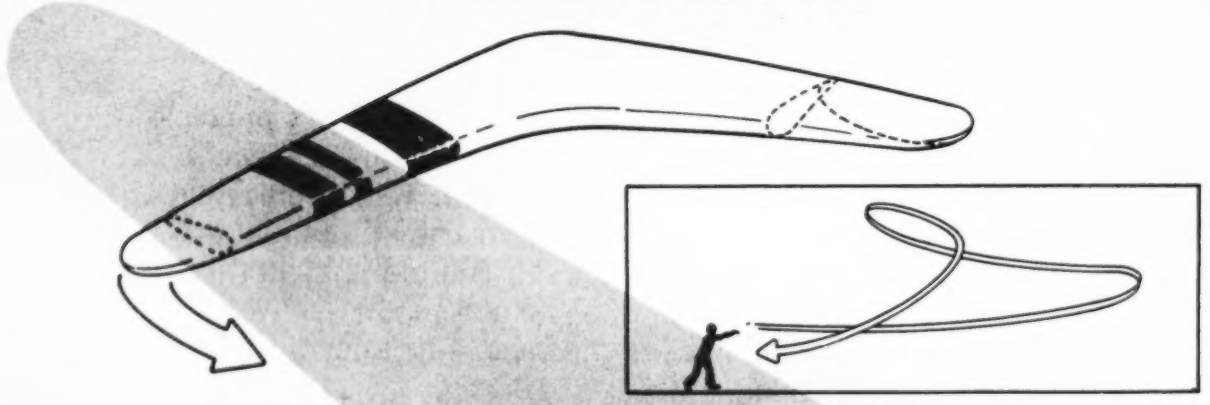
FLYING A BOOMERANG



You have seen the principles of flight at work in airplanes and gliders. A **boomerang** is a device that spins through the air when thrown. If the shape of a boomerang is curved properly, it can be thrown so that it returns to the thrower.

Notice the parts of a returning boomerang. Each wing has a leading edge and a trailing edge. The underside is flat. The boomerang spins forward with the leading edges cutting through the air. Because it is shaped like an airfoil, the air pressure above each wing is lower than below the wing. This gives the boomerang lift. The boomerang gets added lift if the underside of one wing is hollowed out slightly.

ACTIVITY Make a boomerang from medium-weight cardboard, such as that on the back of a pad of paper. Draw the boomerang about 13.7 cm. (5 1/2 in.) along each side. Curve it smoothly along the tips and the center. Carefully bend wings along the midline of their length. Make the leading edges by tracing each wing on paper with at least 10 cm. (4 in.) left to fold over. Carefully fold this leftover paper .6 cm. (1/4 in.) at a time until it folds under the wing. Glue the paper on the top of the wing with the leading edge under the wing. Make sure the leading edge is on the right side of each wing if you are looking down on the wing. Learn to throw the boomerang. Hold the flat part of the boomerang at the end so that the flat bottom faces the palm of your hand. Lean the boomerang to the right side. Practice throwing the boomerang.

1. How are boomerang wings different from airplane wings?_____

_____

2. How is a frisbee like a boomerang?_____

_____

FLIGHT REVIEW

1. A hot-air balloon lifts off because _____

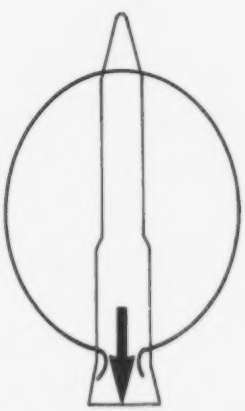
   _____

2. The _____ on the top surface of an airfoil is lower than that beneath it.
3. Lift is the upward force that opposes _____.
4. _____ states that a fluid causes a force to be exerted at a right angle to the surface along which it flows.
5. A faster-flowing fluid causes _____ force than a slower-flowing fluid.
6. The air flowing over the upper surface of an airplane wing travels _____ than the air flowing along the bottom of the wing.
7. The four forces on an airplane are _____.
8. The force on a plane that opposes gravity is called _____.
9. The force that moves a plane forward is called _____.
10. The leading edge of an airplane wing helps overcome _____.
11. _____ is the upward or downward movement of the nose of a plane.
12. _____ is the motion that occurs when one wing dips lower than the other.
13. _____ is the motion of a plane as the nose turns left or right.
14. A pilot can cause a plane to roll to the left by moving the _____ up and the _____ down.
15. A pilot uses the _____ to control pitch.
16. A pilot uses the _____ to turn right or left.
17. A plane is balanced when the _____ is at the same point as the center of lift.
18. Propellers provide _____ for an airplane.
19. Jet engines provide thrust when the action of hot gases being forced from the rear of the jet engine cause _____

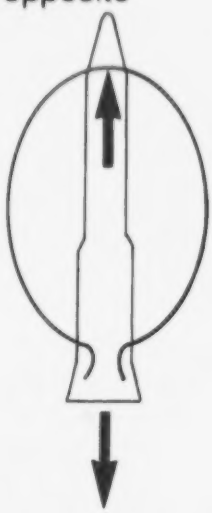
    _____.
20. A _____ can take off or land vertically.

ROCKETS

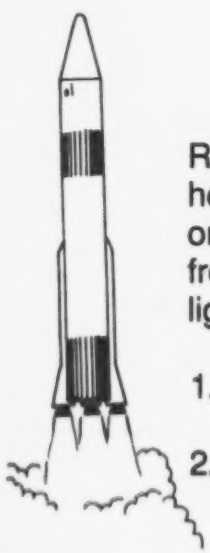
You have learned several facts about flight. You discovered that an airplane must have lift to overcome gravity. It must also have thrust to overcome air resistance. The forces of air resistance and gravity decrease the further from earth a vehicle goes. However, objects must overcome the forces of air resistance and gravity before they reach space. They do this with the help of rockets. Isaac Newton, the famous English mathematician and scientist, discovered one of the most basic laws of physics: for every action, there is an equal and opposite reaction. One example of this is a deflating balloon.



Action:
When the air escapes from the hole of the balloon in one direction...



Reaction:
The balloon moves away in the opposite direction.The same principle that causes the balloon to move also enables a rocket engine's downward thrust to lift a heavy rocket up into space.



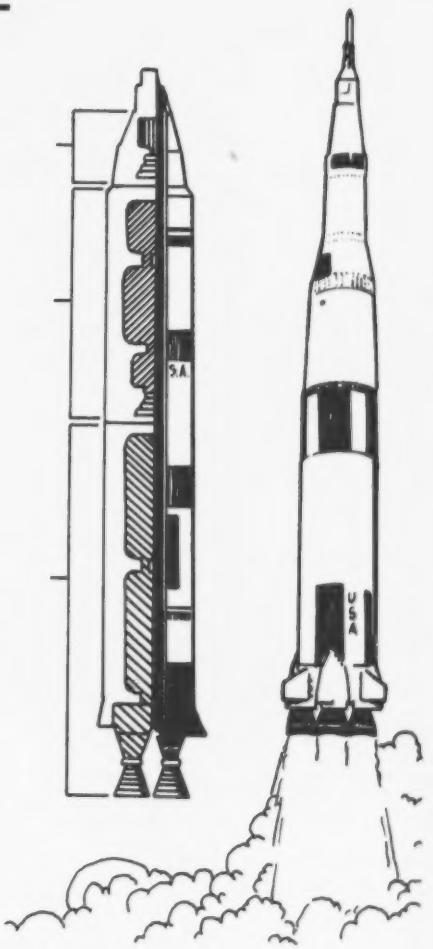
Rocket engines are much more powerful than jet engines. They can lift heavy satellites and spacecraft. For flights into space, rockets have two or more stages. Each stage has a rocket engine and fuel. When the fuel from the first stage is used up, that stage drops off. This makes the rocket lighter. The rocket can then travel much faster.

1. What two forces must a rocket overcome?_____

2. Rockets going into space need more than one stage because _____

_____.

GOING INTO SPACE



A rocket mission carries a **payload** into space. The payload may be a satellite with instruments or a space shuttle that remains in orbit after the other parts of the rocket have been released.

The thrust of a rocket can be expressed in pounds. It must be at least equal to the weight of the rocket. A rocket that weighs 90,000 kilograms (200,000 lbs.) cannot be lifted by a thrust less than 200,000 pounds. A rocket in outer space needs less thrust. It has used up the heavy fuel and has dropped off several stages. Besides, the pull of gravity is much less in outer space.

Space begins at the upper edge of earth's atmosphere. The atmosphere reaches more than 160 kilometers (100 mi.) outward from earth. However, at that distance, the air is too thin to affect objects that move through it. So you can say that space begins about 160 kilometers (100 mi.) from earth.

To launch a rocket, the bottom, or first stage, is ignited. The first stage is much larger than the other stages. It contains enough fuel to lift all the stages of the rocket. The *Saturn V* rocket that blasted off with the Apollo mission that landed astronauts on the moon needed 7,570,000 pounds of thrust to leave the ground. It had three stages. The first stage had five engines. The second stage also had five engines. The third stage had just one engine.

1. Space begins at about _____.

2. A rocket's first stage is so much larger than the other stages because it contains

   _____.

3. The _____ rocket carried the Apollo mission into space with the astronauts who landed on the moon.

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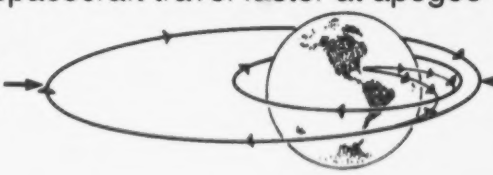
GOING INTO ORBIT

When the first rocket stage blasts off, the spacecraft travels directly upward. After one minute, the rocket begins to arch toward its **orbit**. An orbit is the path of an object as it revolves around another object.

An object moving forward at 8 kilometers (5 mi.) per second above earth stays in orbit. This does not mean that it does not fall toward earth. It falls 5 meters (16 ft.) toward earth every second. But the earth's surface curves downward 5 meters every 8 kilometers. So the object in orbit just keeps falling around earth but never falls to the ground. Traveling 29,000 kilometers (18,000 mi.) per hour keeps the object in orbit.

Does a spacecraft travel faster at apogee or perigee? _____

Apogee: the point on an orbit farthest from earth.



Perigee: the point on an orbit closest to earth.

Most orbits around earth are not circular. They are elliptical, or oval-shaped. An object in elliptical orbit is not always the same distance from earth. The object speeds up when it is closer to earth and slows down when it is farther from earth. An object farther from earth can slow down and still stay in orbit.

ACTIVITY Show how the speed of an object keeps it in orbit. Lay two pieces of dental floss (45 cm. long) crosswise on the table. Stand a plastic cup where the floss crosses. Bring the ends of the floss up around the cup and secure the floss with tape around the middle of the cup. Tie a knot where the four ends of the floss meet above the cup. Pour about 5 cm. of water in the cup. Then hold the floss at the knot and swing the cup in a swift, circular orbit.

1. What happens to the water? _____ Why? _____

2. Slow the swinging motion. What happens now? _____

   Why? _____

3. What keeps an object traveling in orbit from falling to earth? _____

4. Give two reasons why an object farther from earth takes longer to orbit the earth.

   _____

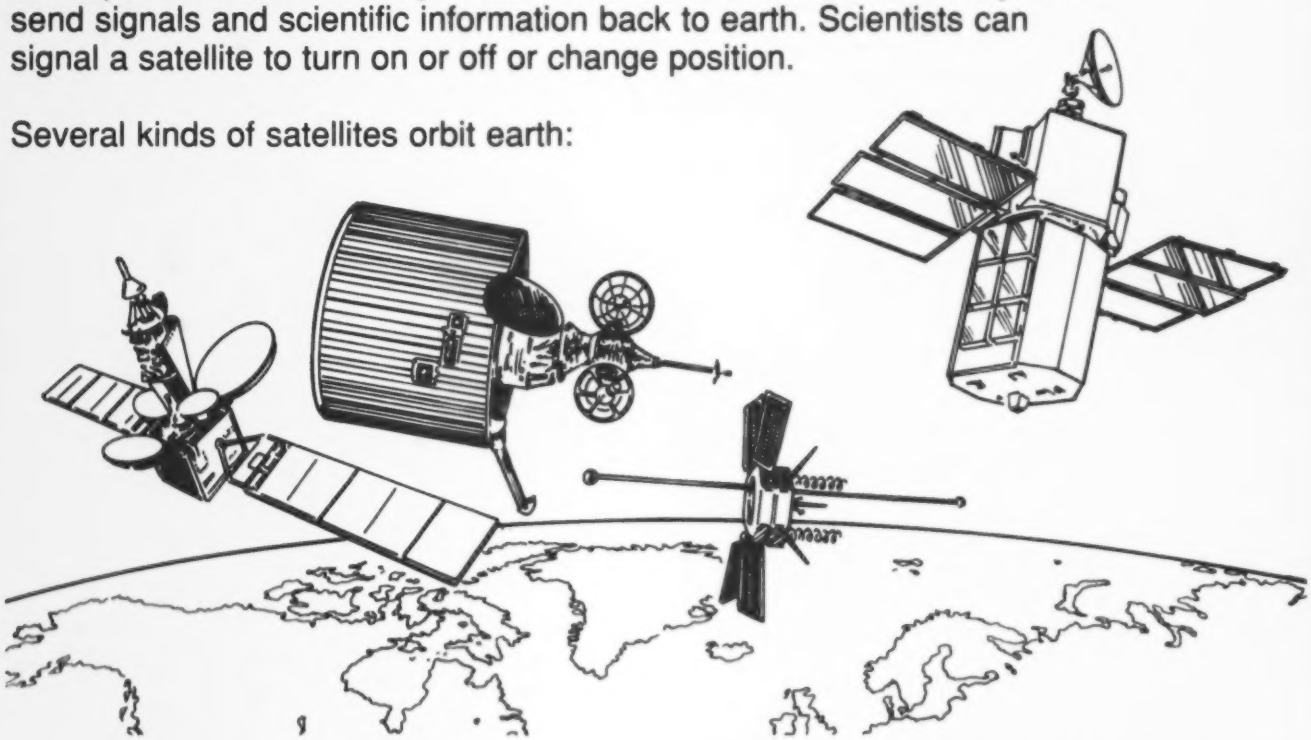
   _____

SATELLITES

A **satellite** is an object that revolves around another object. Earth has one natural satellite, the moon. There are also many artificial satellites around earth. The artificial satellites were made by scientists and put into orbit in the last 30 years.

A satellite must travel at a certain speed if it is to stay in orbit. If it slows down, it leaves orbit and falls back toward earth. It will burn up in the atmosphere. Satellites carry a radio transmitter and receiver. They can send signals and scientific information back to earth. Scientists can signal a satellite to turn on or off or change position.

Several kinds of satellites orbit earth:



INTELSAT
Communication
(relays telephone calls, TV programs)

GOES
Weather
(relays pictures of atmosphere)

NAVSTAR
Navigation
(helps ships to determine position)

SOLAR MAXIMUM
Scientific
(observes sun)

ACTIVITY

1. How do you think the satellites were put into orbit?_____

_____

2. What are some uses of satellites?_____

3. What happens if a satellite loses speed?_____

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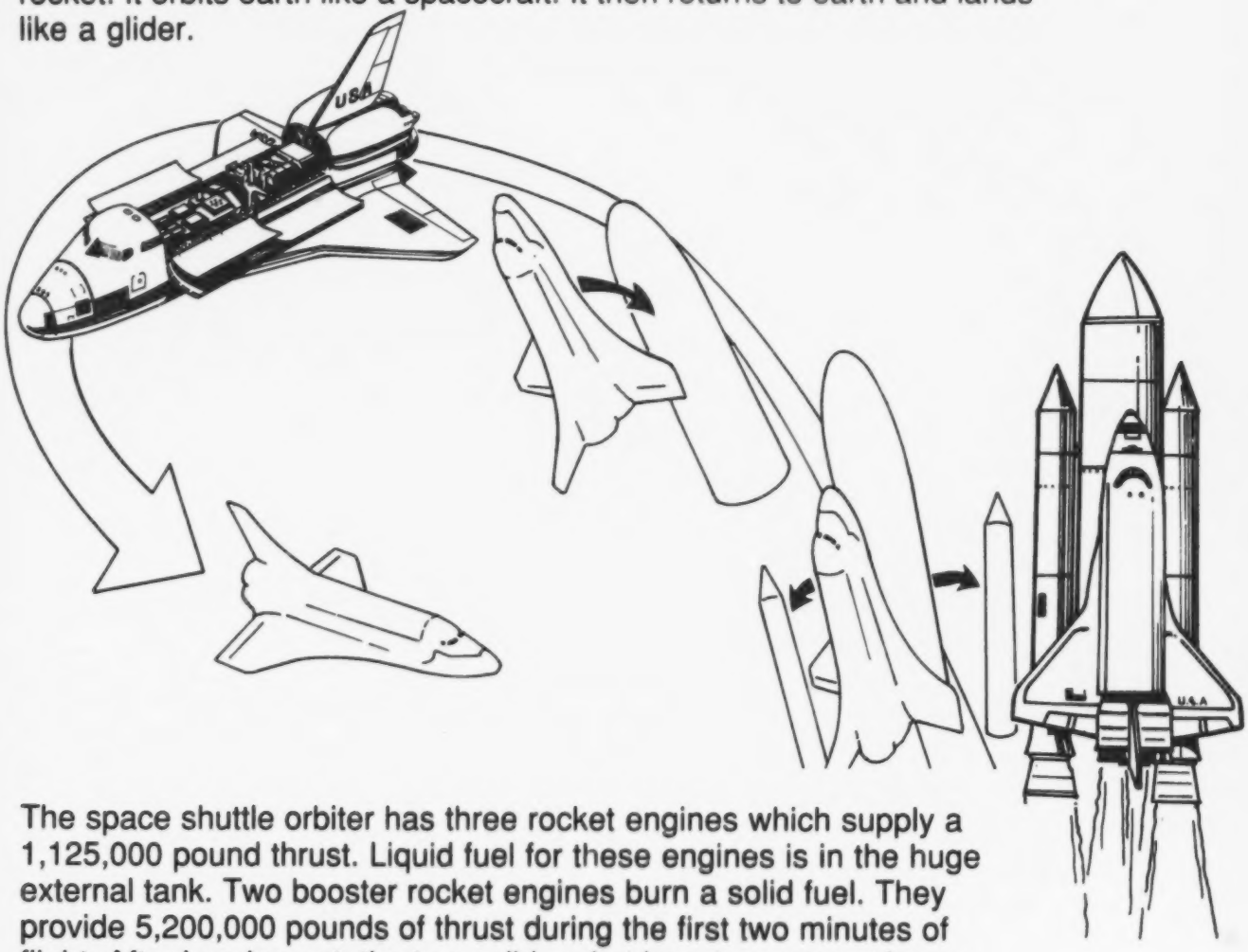
SPACE SHUTTLE

The space shuttle is three flight vehicles in one. It is launched like a rocket. It orbits earth like a spacecraft. It then returns to earth and lands like a glider.



The space shuttle orbiter has three rocket engines which supply a 1,125,000 pound thrust. Liquid fuel for these engines is in the huge external tank. Two booster rocket engines burn a solid fuel. They provide 5,200,000 pounds of thrust during the first two minutes of flight. After burning out, the two solid rocket boosters are cut loose from the external tank. They fall to earth in an area of the ocean where they are recovered.

The external tank is carried by the orbiter almost into orbit. About eight minutes after takeoff, the tank has been emptied. It separates from the orbiter and falls into the ocean. The orbiter then goes into orbit. It can stay in space up to 30 days depending on the size of the crew.

ACTIVITY Make a paper model of the space shuttle. Include these parts: orbiter, external tank, solid rocket boosters. Use your model to explain how the shuttle gets its thrust. Also discuss why the space shuttle does not land like a plane.

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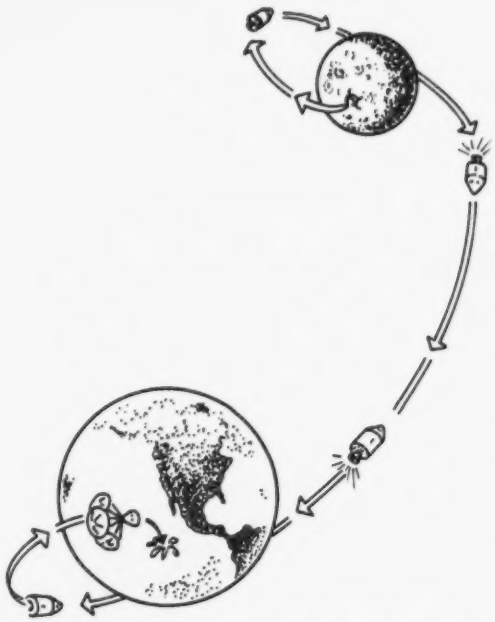
RETURNING FROM SPACE

The astronauts returned from the moon in the Apollo command module. This spacecraft had been in orbit around the moon, while two of the astronauts walked on the moon. A service module with the engines and fuel was connected to the command module.



When the engine of the service module was fired, the modules left the orbit around the moon. The service module was released, and the command module was turned around with its blunt end facing forward to slow it down as it entered earth's atmosphere.

At 7 kilometers (23,300 ft.), parachutes were released to steady the command module and slow it further. The module hit the water at a speed of 35 kilometers (22 mi.) per hour.

When it is time for the space shuttle orbiter to land, it turns around with its tail facing forward. The rocket engines are fired about an hour before landing to slow down the orbiter. When it reaches the proper speed, the orbiter's nose is turned around to face forward again. The nose is pointed upward at an angle. The orbiter begins entry at a speed of 26,500 kilometers (16,500 mi.) per hour. Atmospheric drag heats it up to temperatures as high as 1510°C (2,750°F). The intense heat strips electrons from the air around the orbiter. This blocks communication with earth for 12 minutes.

As the orbiter descends, it becomes a glider. It descends at 3000 meters (10,000 ft.) per minute. During several steps, the ailerons, then the elevators, and finally the rudders are used.

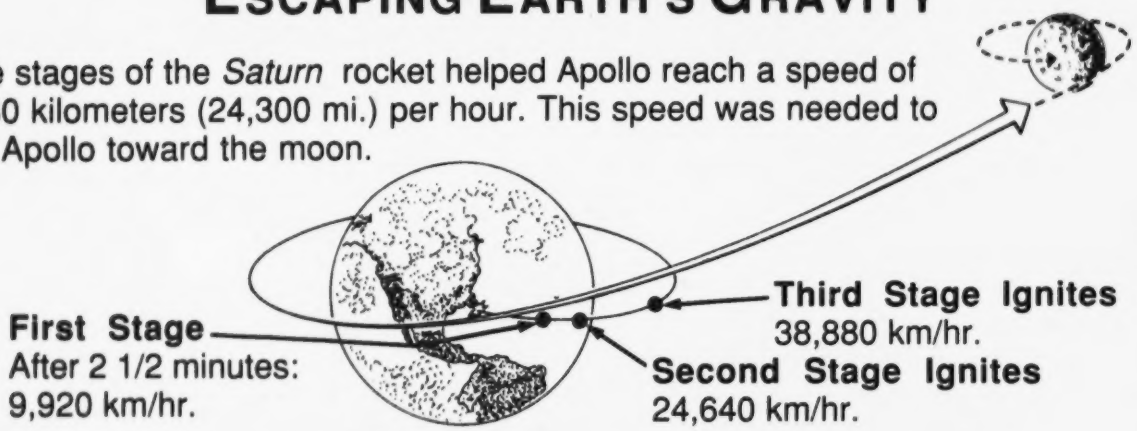
ACTIVITY

1. Turning a space vehicle around before firing the rocket engines causes the space vehicle to slow down. **T F**
2. The space shuttle orbiter was slowed down by parachutes. **T F**
3. The orbiter lands like a glider. **T F**
4. The orbiter lands in the water. **T F**
5. The space shuttle has a faster landing speed than the Apollo command module. **T F**

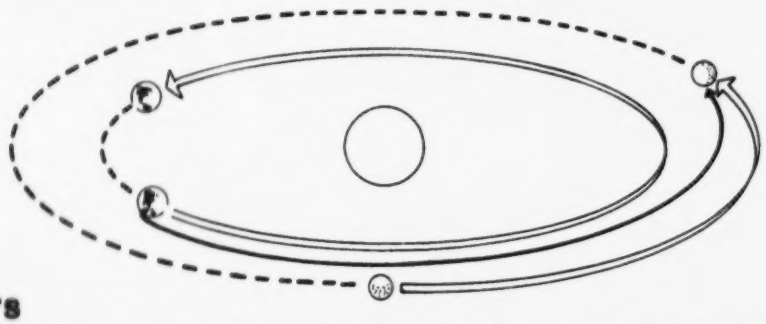
32

ESCAPING EARTH'S GRAVITY

Three stages of the *Saturn* rocket helped Apollo reach a speed of 38,880 kilometers (24,300 mi.) per hour. This speed was needed to send Apollo toward the moon.



The speed needed to escape earth's gravity is called **escape velocity**. When a spacecraft reaches 40,000 kilometers (25,000 mi.) per hour, it can escape the influence of earth's gravity. It then goes into orbit around the sun.



Going to Mars

During your lifetime a team of astronauts may land on the planet Mars. To do this, their spacecraft will have to be launched faster than the *Saturn* rocket. A spacecraft going to Mars must be launched at a speed even greater than escape velocity. A spacecraft launched at a speed of 42,620 kilometers (26,640 mi.) per hour will go into a special orbit around the sun. This special orbit will lead right to Mars.

ACTIVITY

1. A spacecraft needs a speed of _____ per hour to travel to the moon.

2. To escape earth's gravity a spacecraft needs a speed of _____ per hour.

3. A spacecraft must travel at a speed of _____ per hour to go to Mars.

4. When a spacecraft leaves earth's orbit, it goes into orbit around _____.

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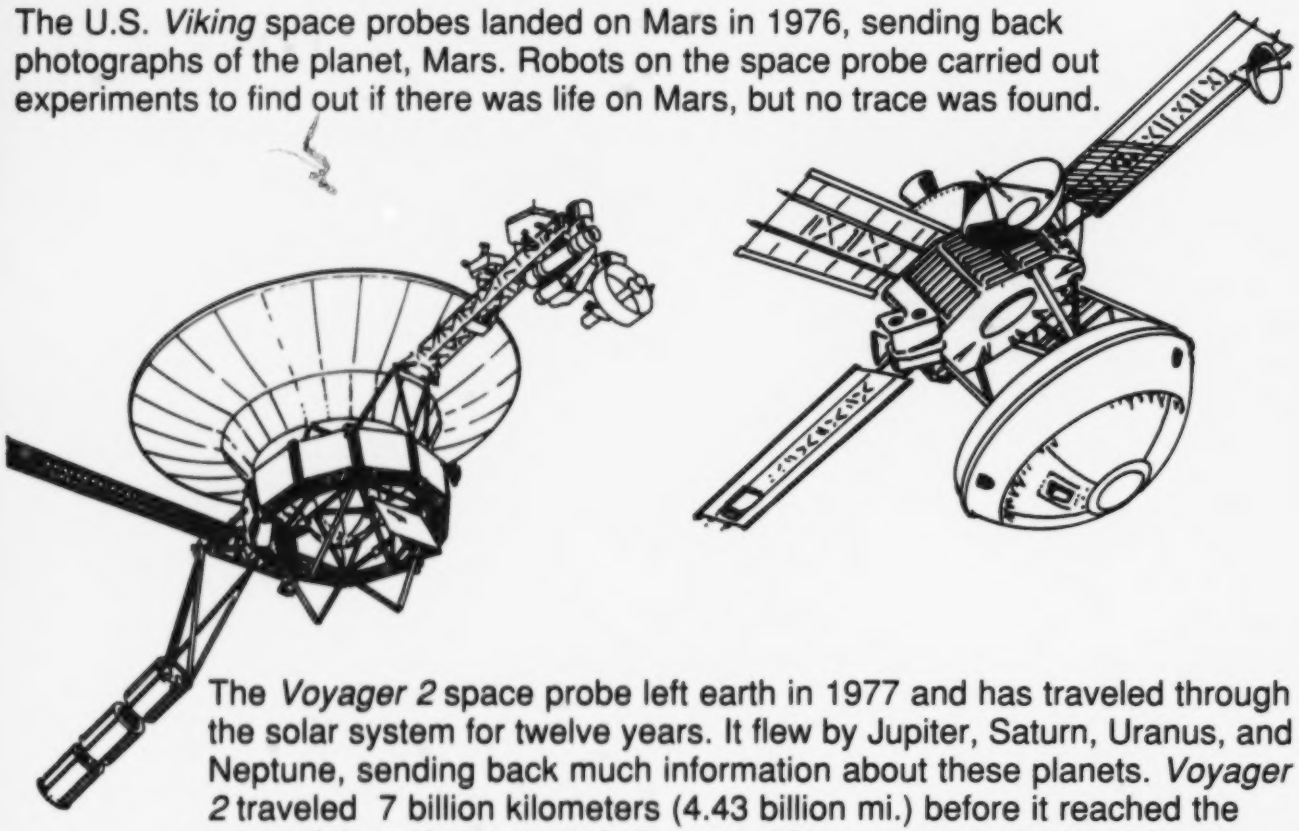
SPACE PROBES

Space probes are spacecraft that explore space without passengers aboard. They may fly by their targets, orbit around them, or even land on them. Since 1962, fifteen American space probes have flown by or landed on all the planets except Pluto.

The U.S. *Viking* space probes landed on Mars in 1976, sending back photographs of the planet, Mars. Robots on the space probe carried out experiments to find out if there was life on Mars, but no trace was found.



The *Voyager 2* space probe left earth in 1977 and has traveled through the solar system for twelve years. It flew by Jupiter, Saturn, Uranus, and Neptune, sending back much information about these planets. *Voyager 2* traveled 7 billion kilometers (4.43 billion mi.) before it reached the edge of the solar system. It then used Neptune's gravitational force as a slingshot to send it into deep space. Some space probes have panels of solar cells to produce electricity. *Voyager's* electrical power comes from **plutonium oxide**, a nuclear fuel that gives off heat as it decays.

ACTIVITY

1. Experiments were carried out on Mars by _____.
2. The _____ space probes landed on Mars.
3. *Voyager 2* flew by _____ planets during a trip of _____ kilometers which took _____ years.
4. After *Voyager 2* flew by _____ it left the _____ and went into _____.

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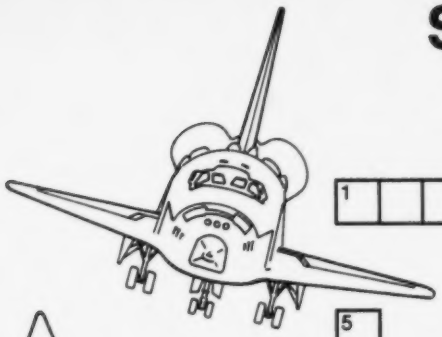
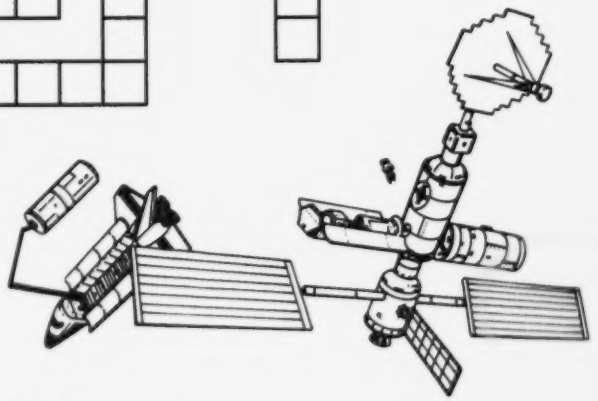
SPACE REVIEW





ACROSS

1. The engines that lift heavy satellites and spacecraft into space are called _____.
3. The space mission that landed astronauts on the moon was called _____.
6. Most orbits around earth or the sun are _____, or oval-shaped.
9. A flight vehicle called the _____ is launched like a rocket and lands like a glider.
10. _____ begins at the upper edge of earth's atmosphere, more than 160 kilometers (100 mi.) outward from the surface of earth.
11. A space probe called _____ has now traveled out of the solar system.

DOWN

2. _____ are objects that revolve around another object.
4. A(n) _____ is the path of an object as it revolves around another object.
5. Spacecraft that explore space without passengers aboard are called _____.
7. The point in the orbit of an object revolving around earth that is closest to the center of earth is _____.
8. The point in the orbit of an object revolving around earth that is farthest from the center of earth is _____.
9. The name of the rocket that launched the astronauts to the moon is _____.

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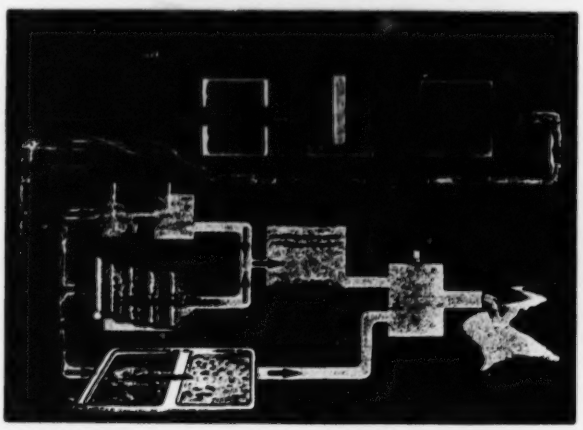

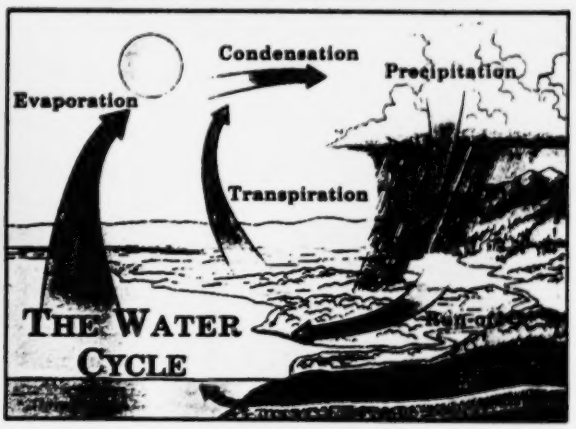

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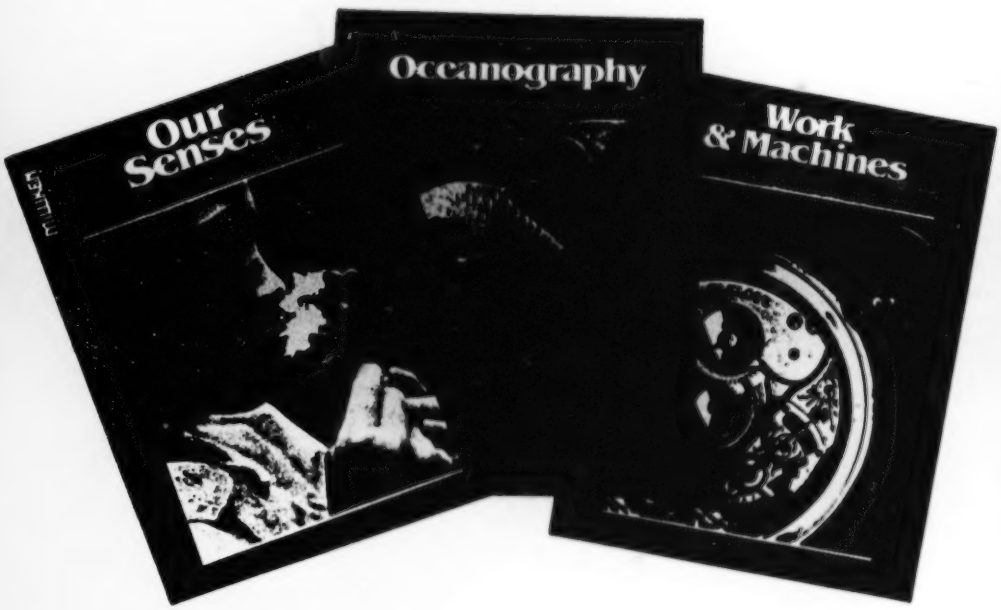

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